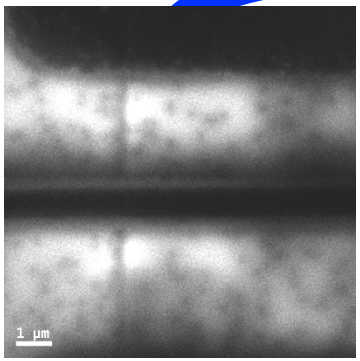
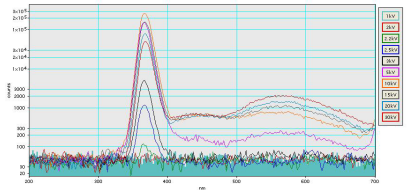
CL and PL Characterization

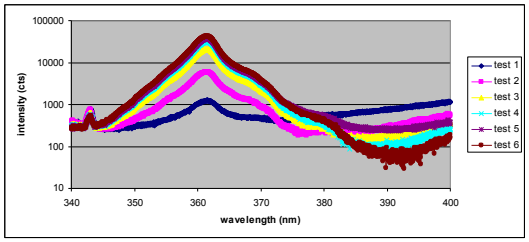
FLOORS



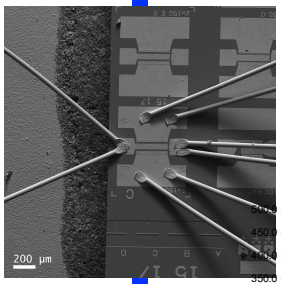
CL on pre stressed device



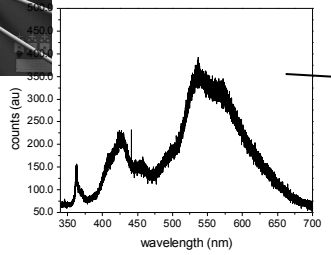
CL depth profiling

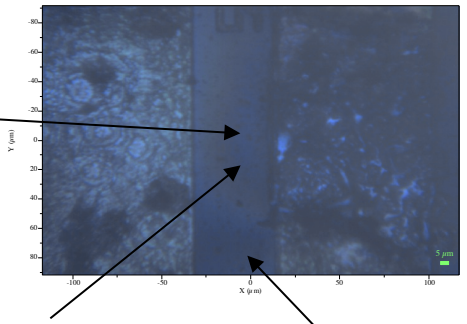


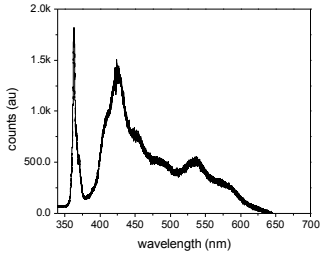
PL on bulk epi and pre stressed devices

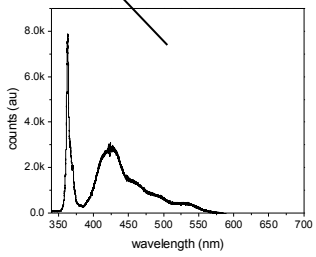


PL on post stressed devices









t=0, As Built

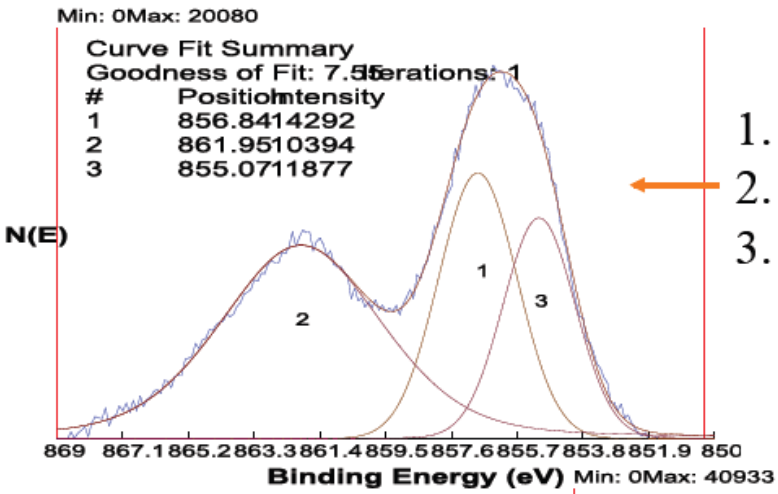
t>0, Degradation

XPs Analysis of Metal/Nitride Interface
&
Cathodoluminescence and Photoluminescense of AlGaN/GaN devices

Erica Douglas, Danny Zeenberg, Midori Maeda, Brent Gila, Cammy Abernathy

XPS study of 1nm Ni/AlGaN

Pre-vacuum anneal

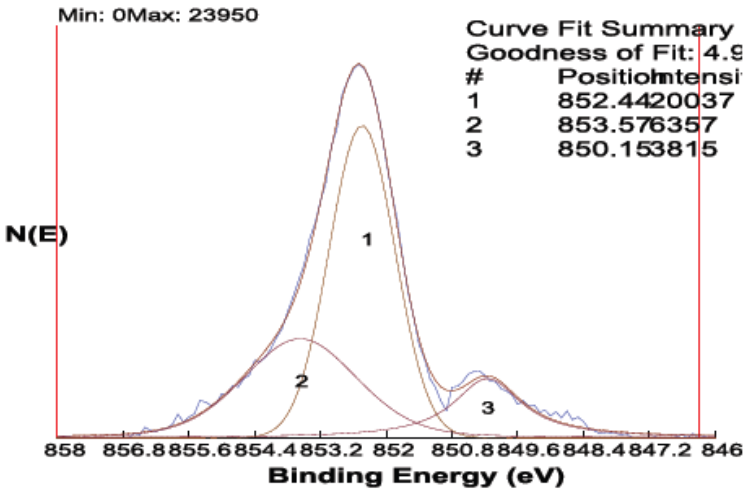


Ni $2p_{3/2}$ Peak

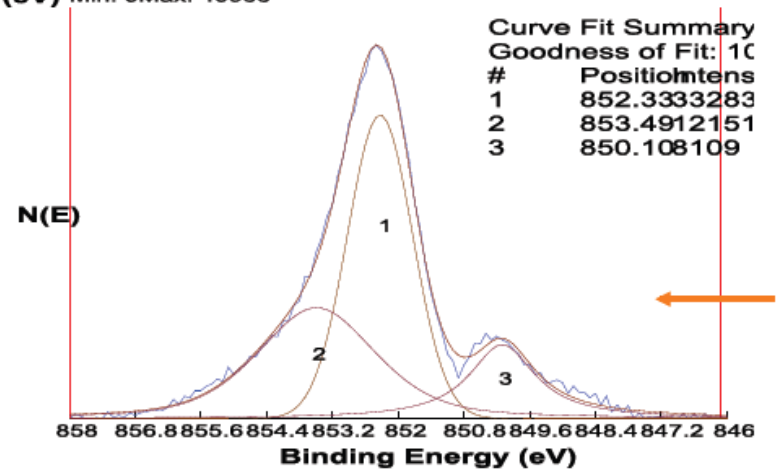
Curves:

1. Ni-O
2. Ni satellite
3. Ni metal

Post-vacuum anneal



Vacuum anneal 300ºC



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2. Ni-O satellite
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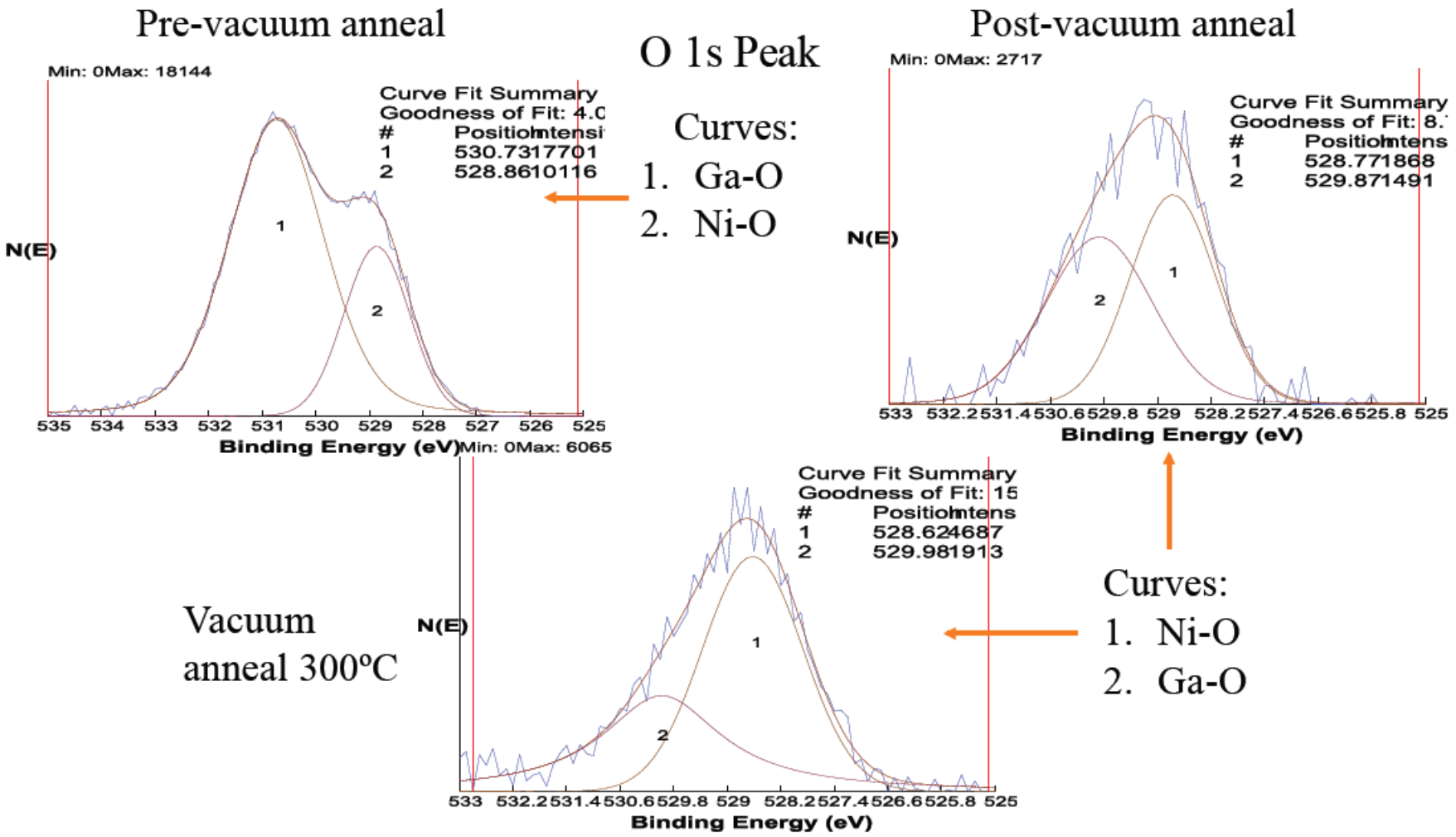
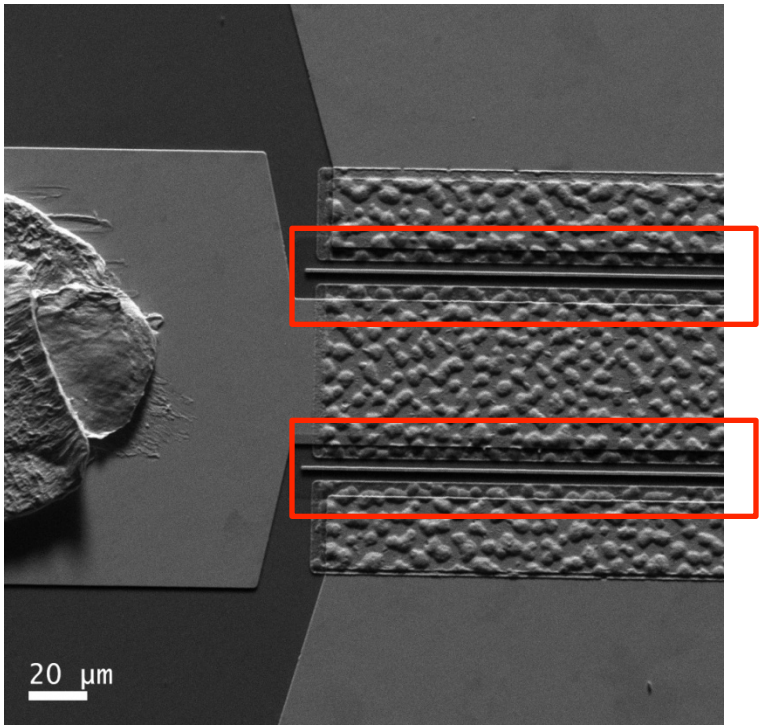
XPS study of 1nm Ni/AlGaN



Cathodoluminescence Experiment

- Analysis is done before and after failure
- Area of interest is in the channel/gate region

- Accelerating voltages were varied from 1keV to 30keV



Depth Dependence of CL Signal

- The penetration depth of the incident beam varies according to the following equation:

$$R(\mu m) = (0.052/\rho) * E^{1.75}$$

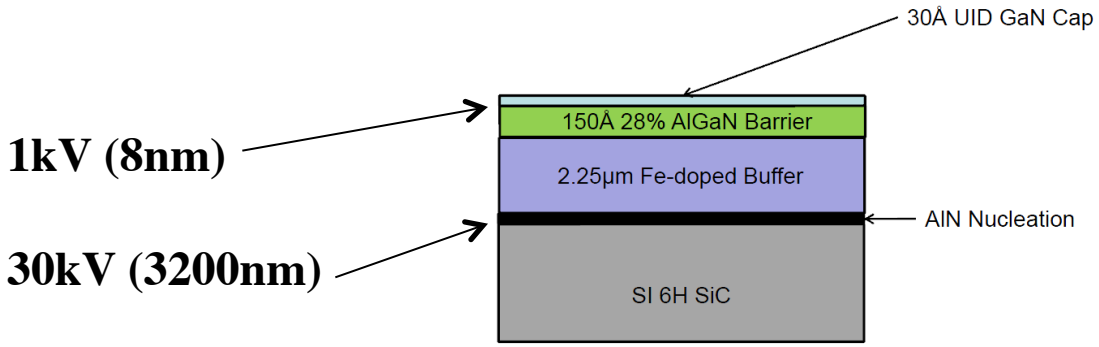
With: $\rho(GaN) = 6.1 g/cm^3$

2 kV ~ 30 nm

5 kV ~ 200 nm

30 kV ~ 3200 nm

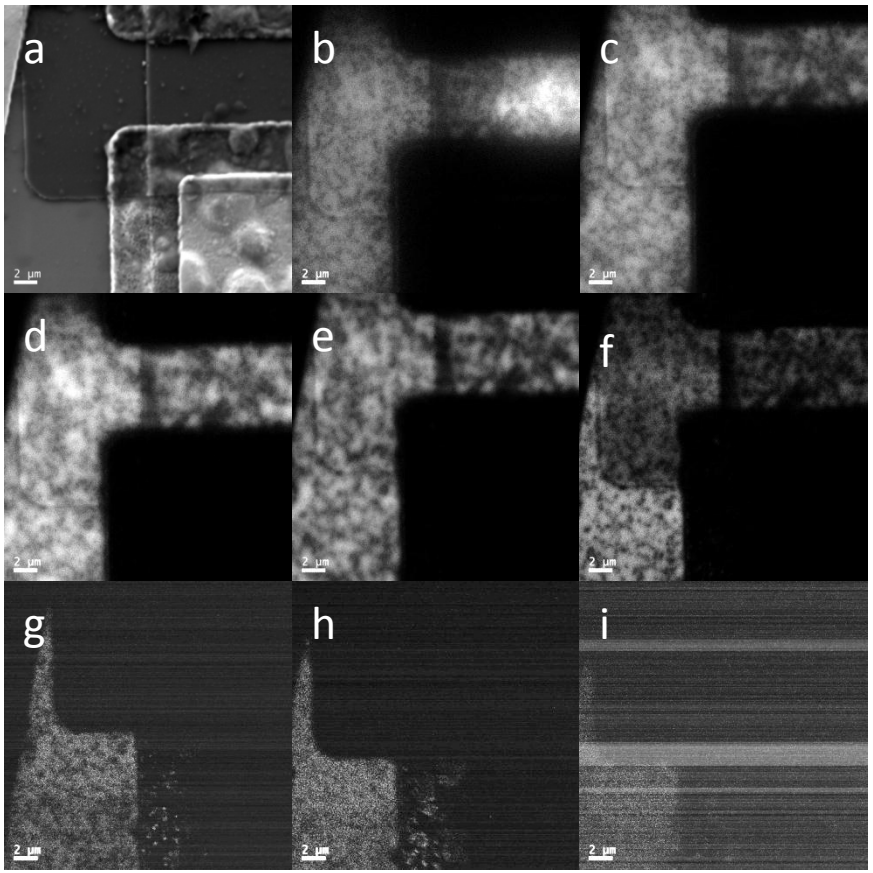
- The thickness of the passivation layer is ~200 nm



"Cathodoluminescence depth-profiling studies of GaN/AlGaN quantum-well structures" M. Godlewski, J. Mater. Res. Vol 15 No. 2 (2000)

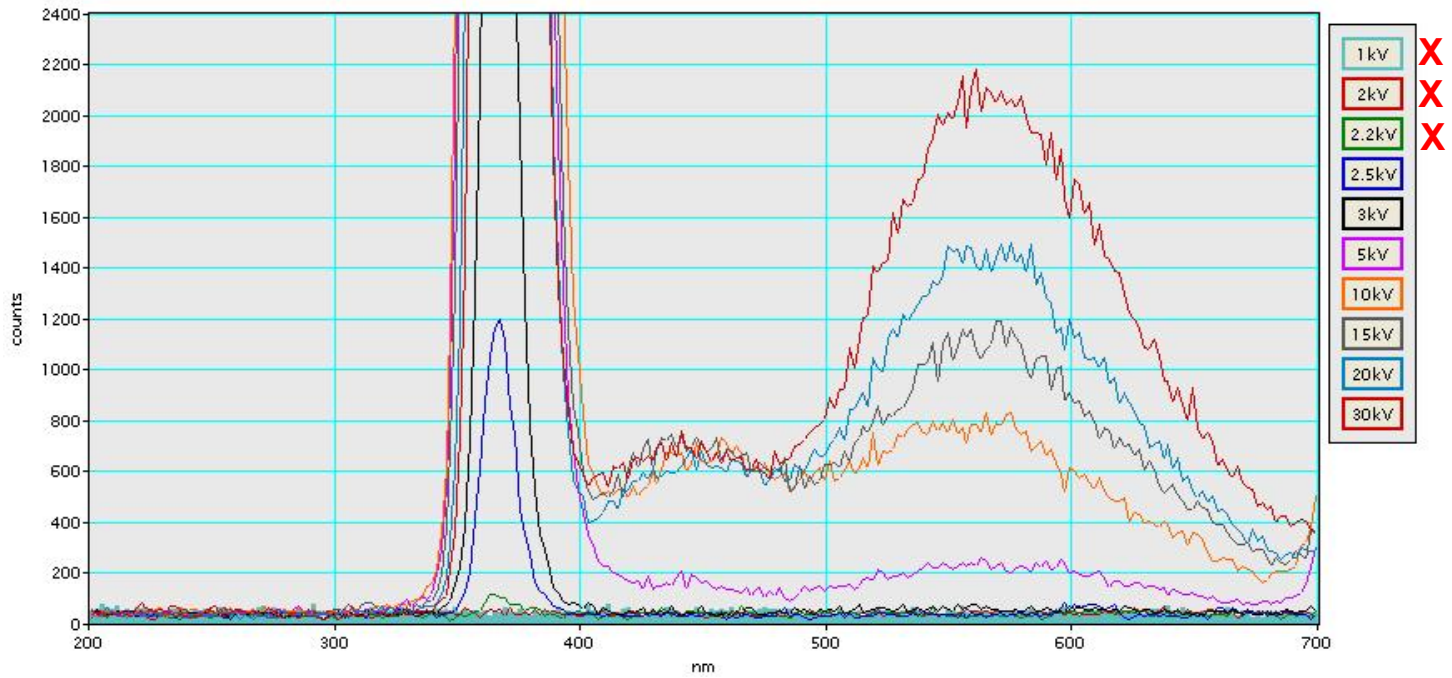
Depth Dependence of CL Signal

a) SE image 10kx
b) 30kV CL image
c) 20kV CL Image
d) 15kV CL image
e) 10kV CL Image
f) 5kV CL image
g) 3kV CL image
h) 2kV CL image
i) 1kV CL image



Threading Dislocations are non-radiative defects. Hino et al, *Appl. Phys. Lett.*, Vol. 76, No. 23 (2000)

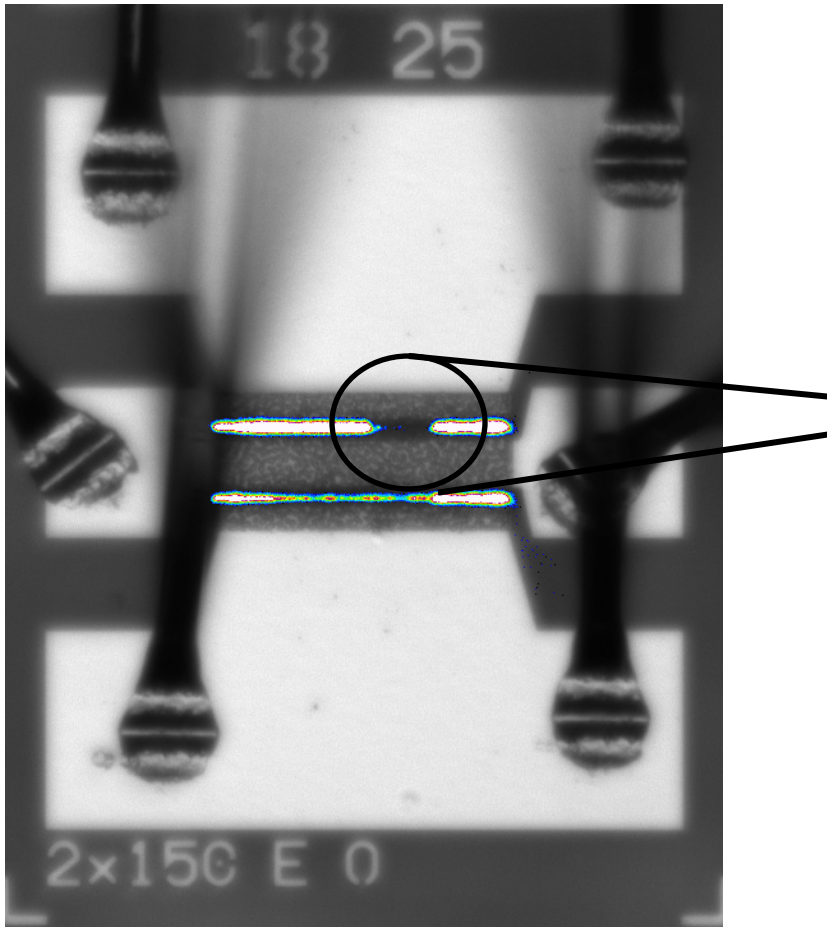
Defect Peaks

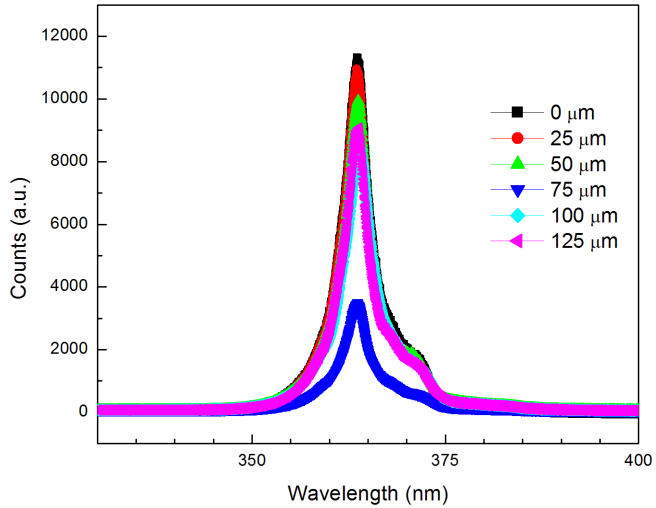


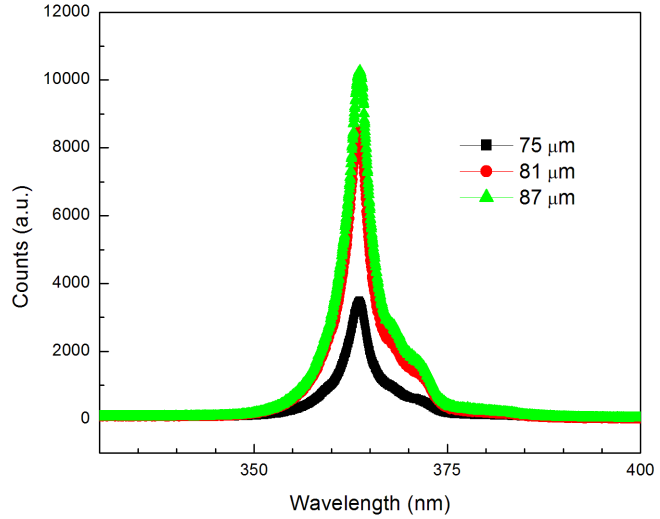
- Yellow (556nm) and blue (440 nm) luminescent signals are visible defect peaks
- The Blue defect is stationary until we drop to 5kV while the Yellow defect increases steadily with voltage

Sub 5kV CL spectra has insufficient photon counts

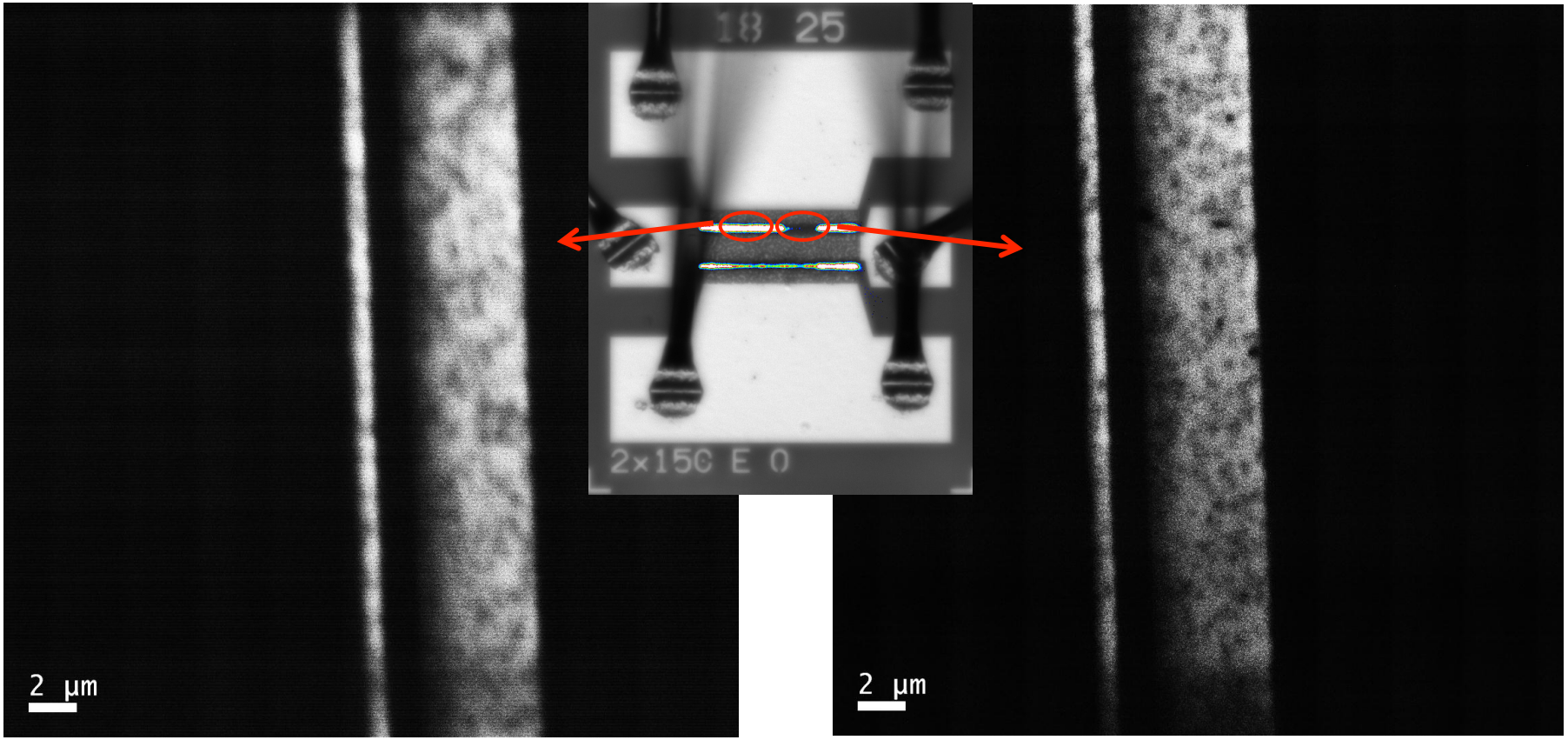
Stressed AFRL Device







Stressed AFRL Device - CL Images

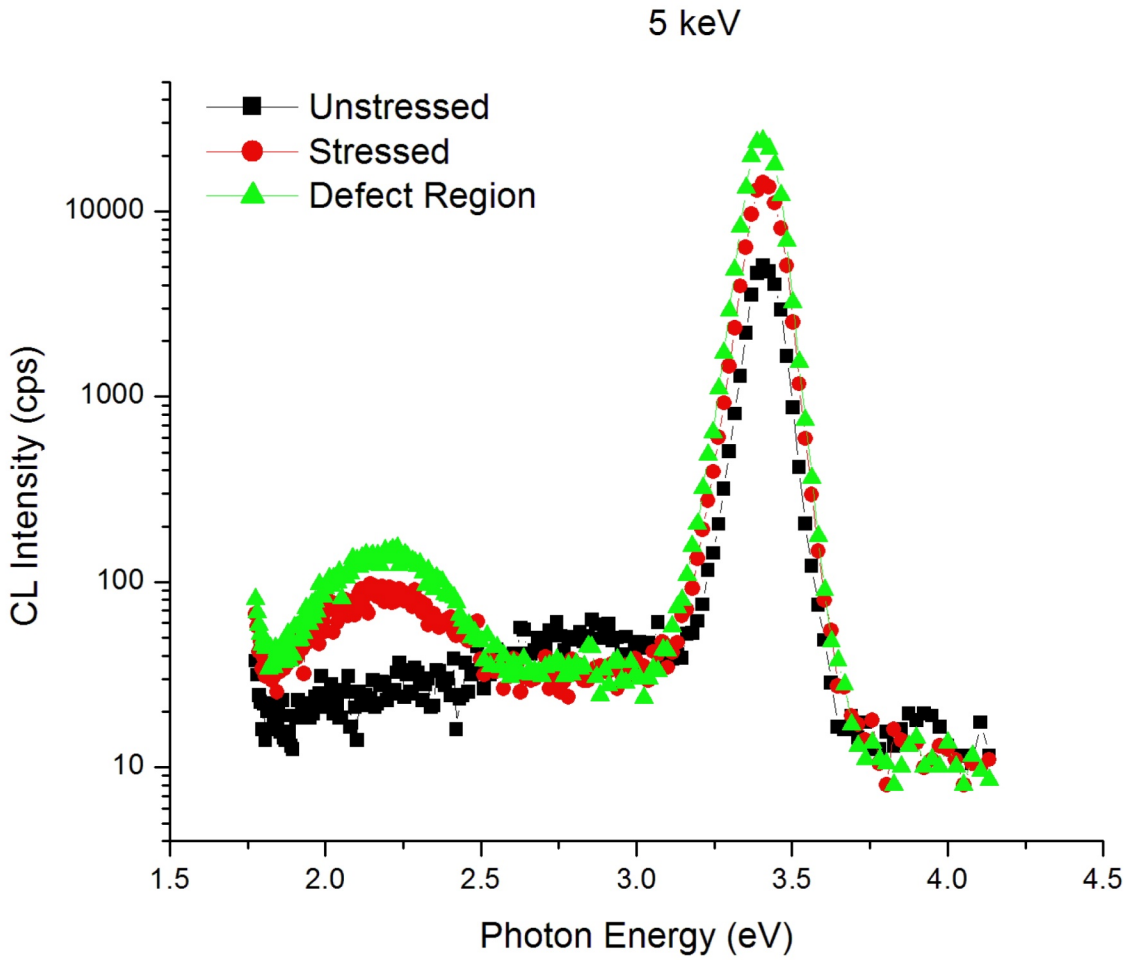


3kV, 25kx

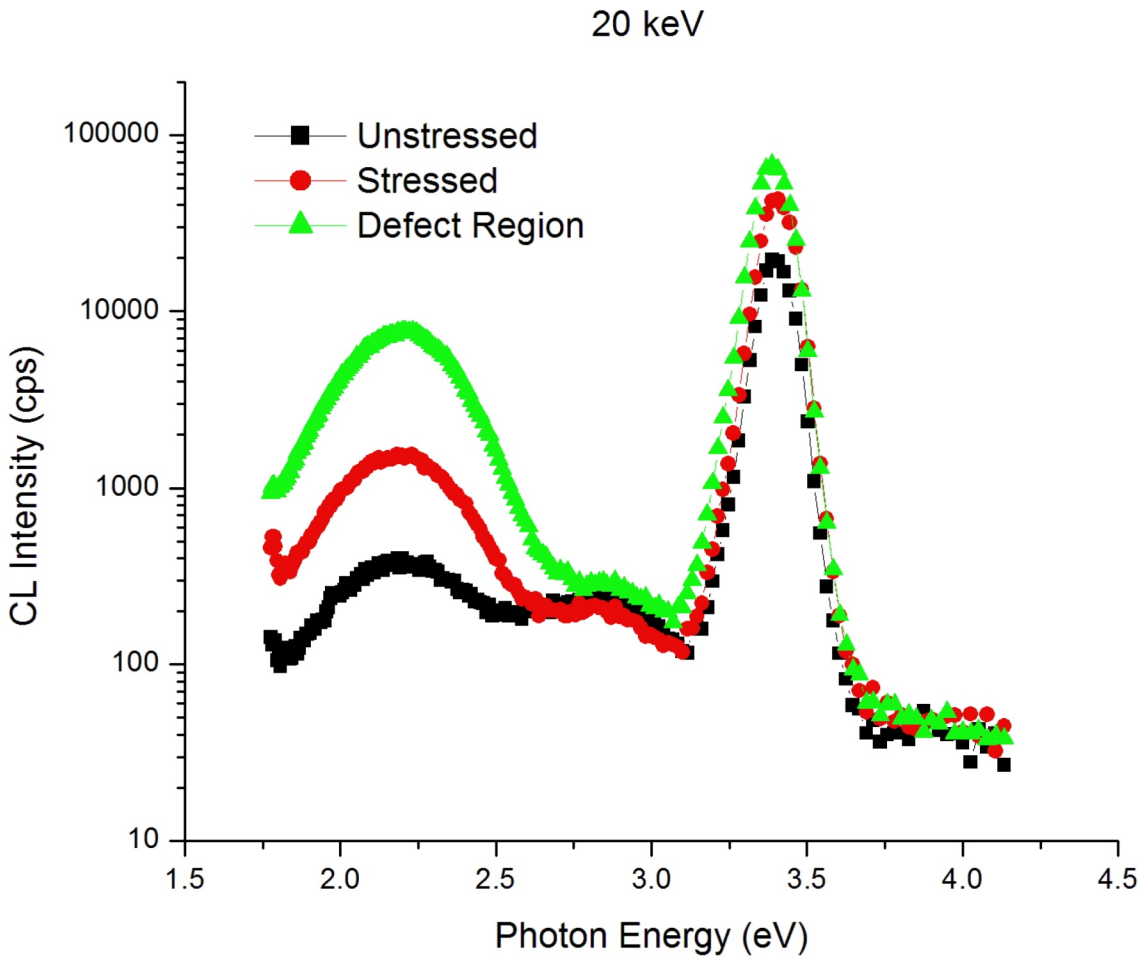
Threading dislocations appear more near surface in dark EL region of channel.

0.125 μm gate length, 10 GHz, 3.7 dB compression, I_{DQ} =200mA/mm, Class AB, AFRL Device # 1825B

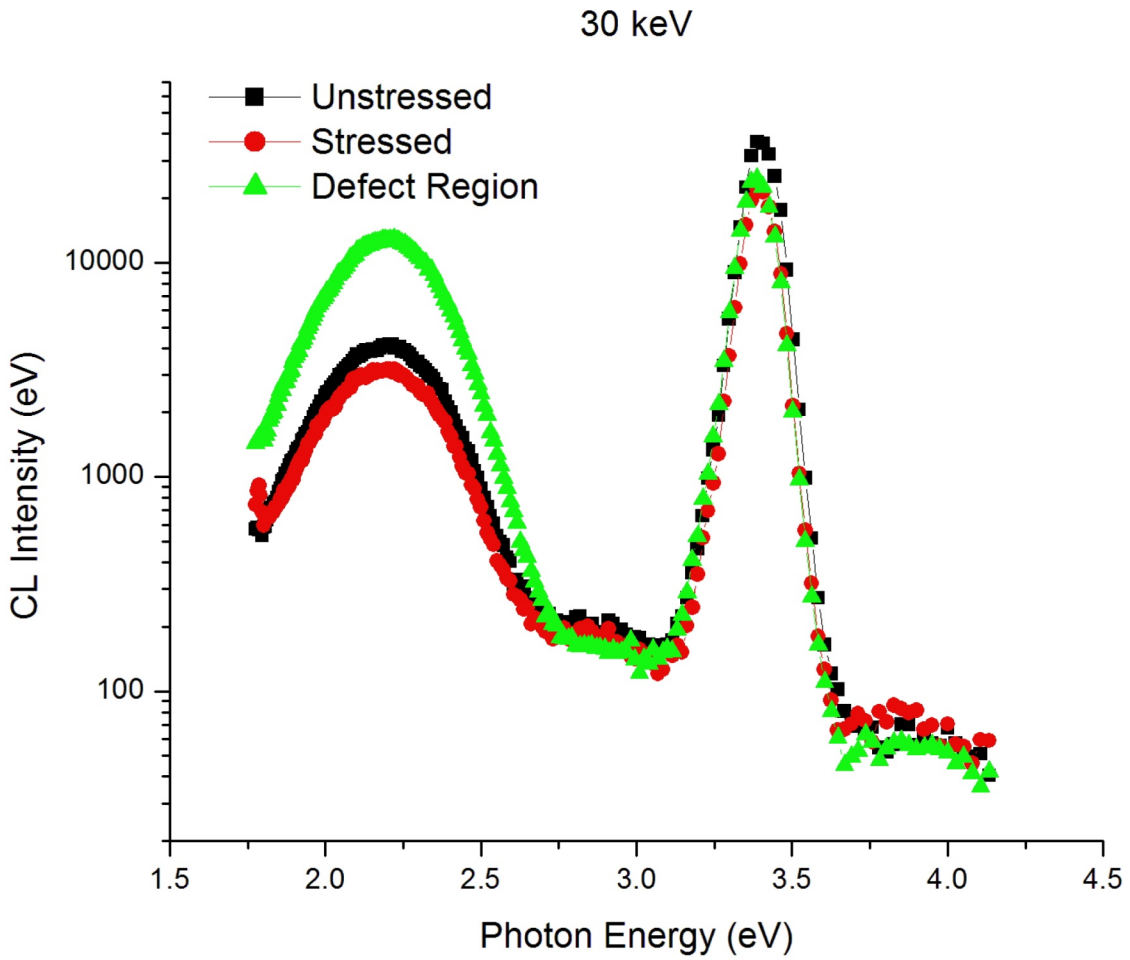
Stressed AFRL Device - CL Spectra



Stressed AFRL Device - CL Spectra

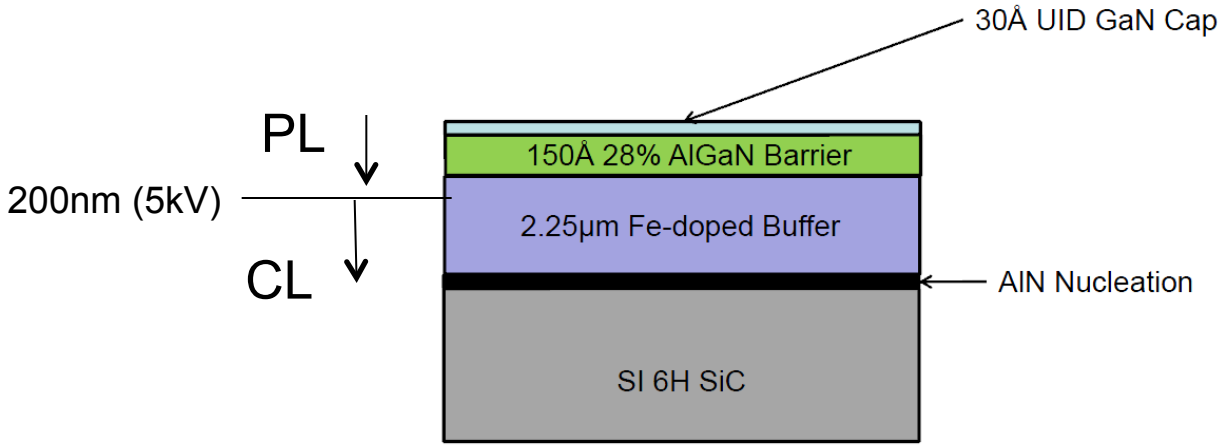


Stressed AFRL Device - CL Spectra

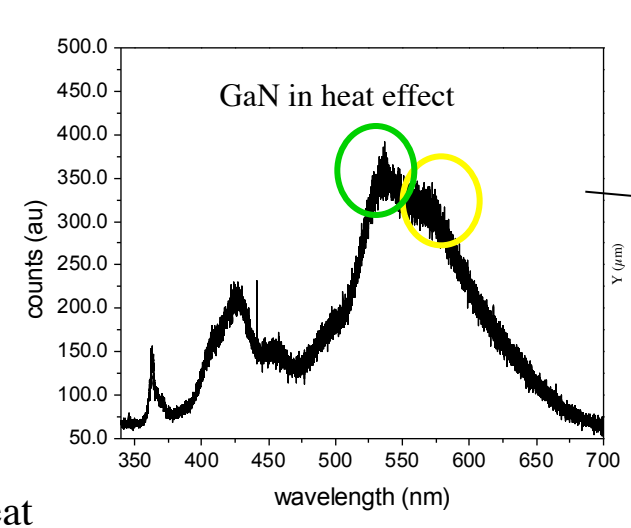


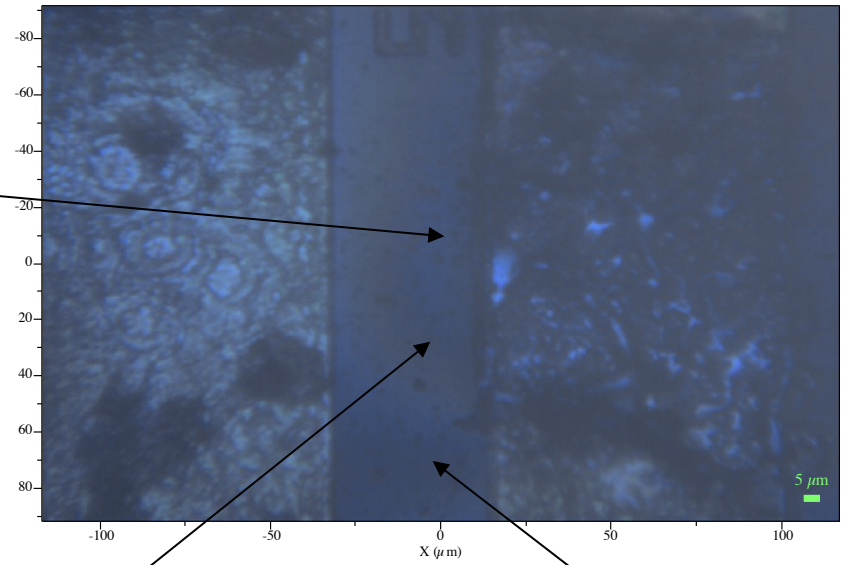
Photoluminescence Experiment

- Photoluminescence was conducted on the Horiba MicroRaman tool utilizing the 325nm He-Cd laser
- A previously stressed device was measured to attempt to locate the degraded portion of the channel and identify any underlying defect spectrum



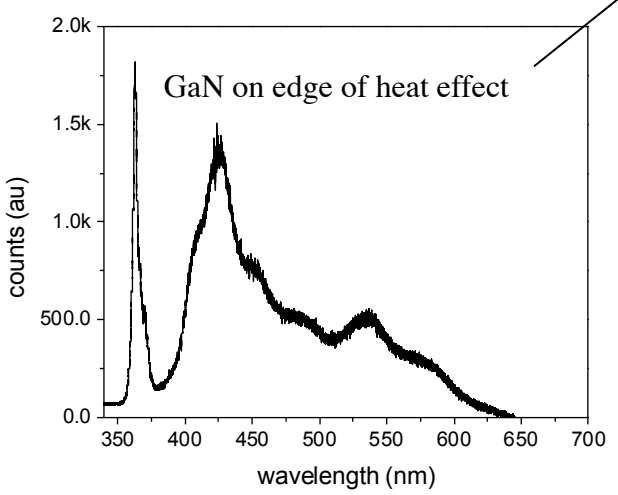
Conventional AlGaN/GaN HEMT TLM analysis

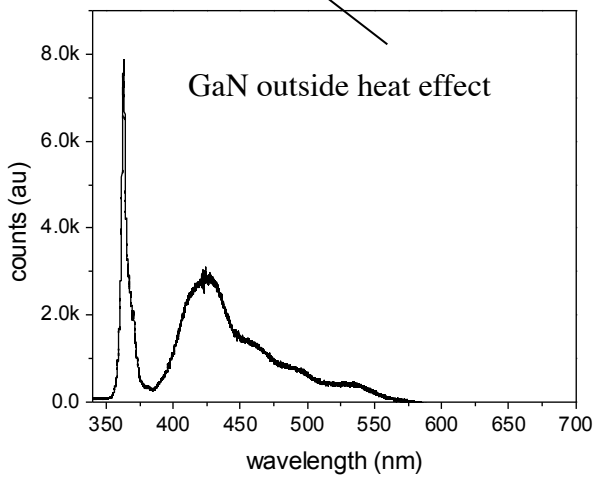




Analysis of heat effected region on side of ohmic contact.

Evolution of green and yellow defects due to extreme contact heating.





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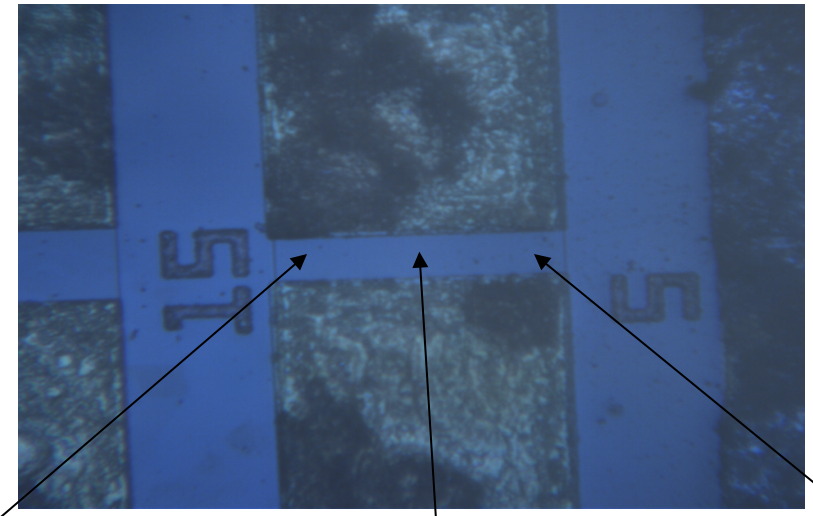

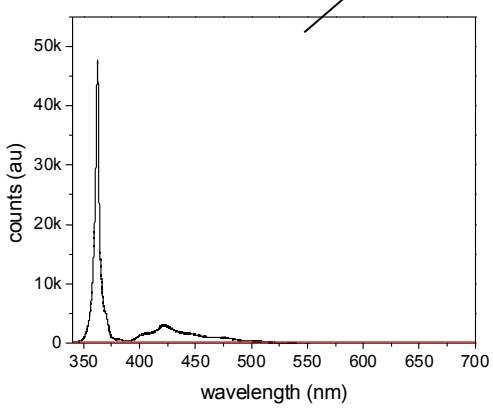

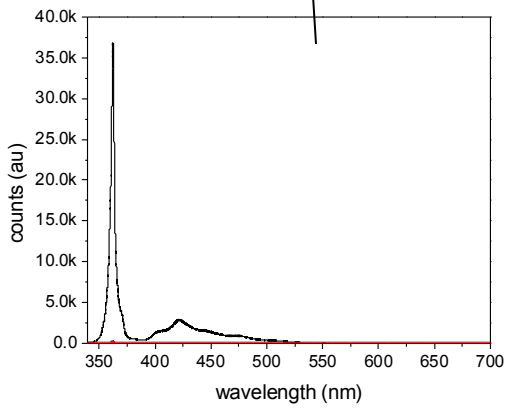

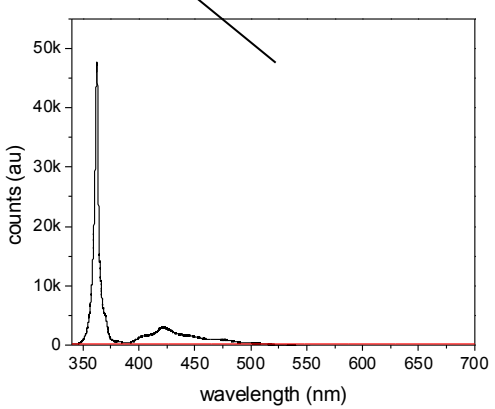

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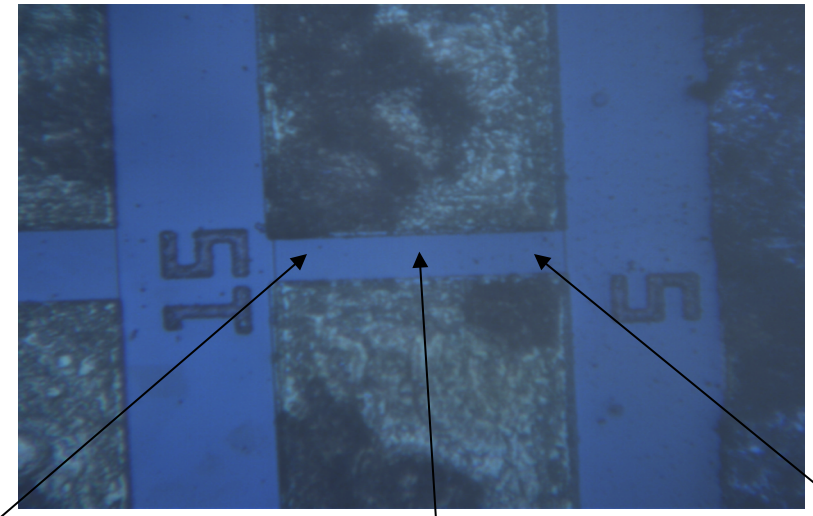
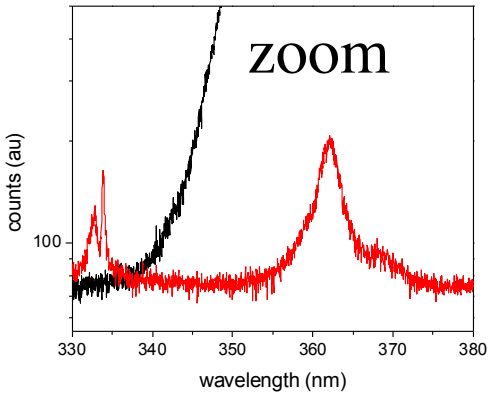
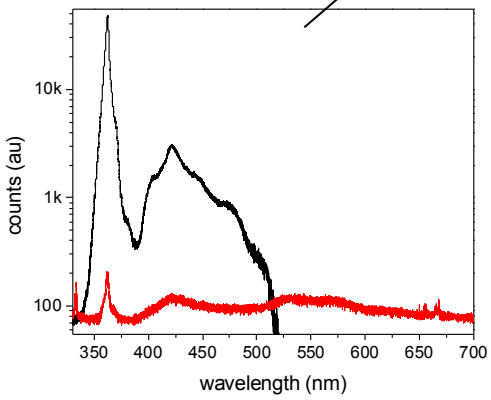
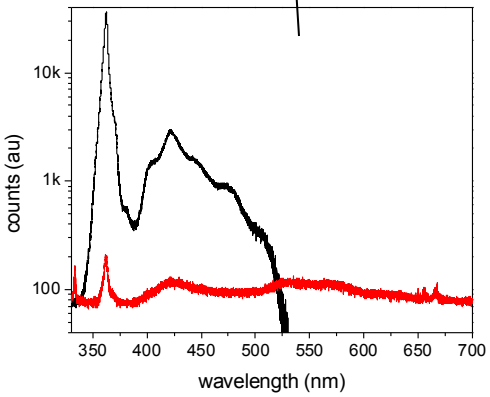
In log scale, a higher energy peak is seen post stress. Associated with an AlGaN layer… but which one?

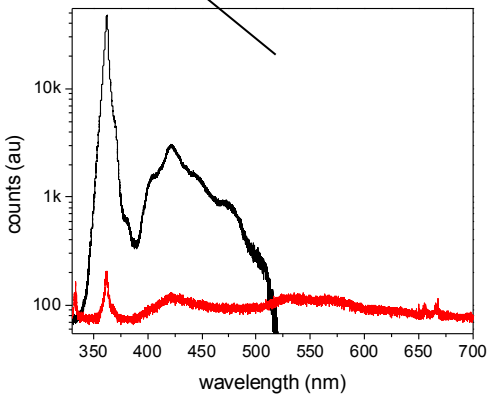
332.9nm = 3.72eV
333.8nm = 3.71eV
~$Al_{0.11}Ga_{0.89}N$











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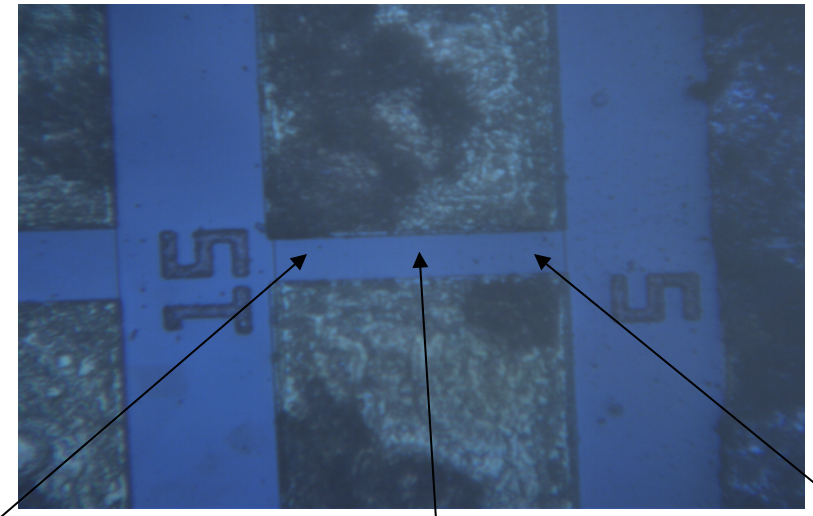
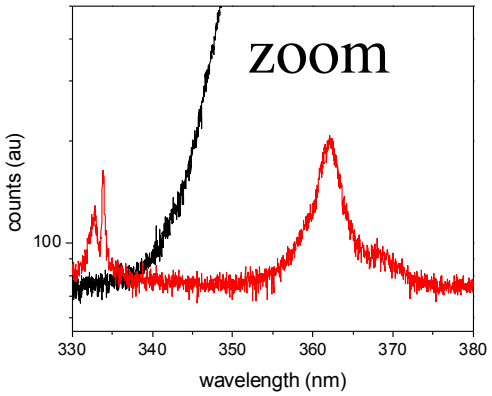
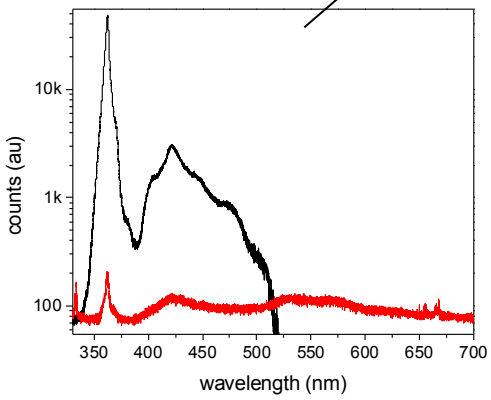
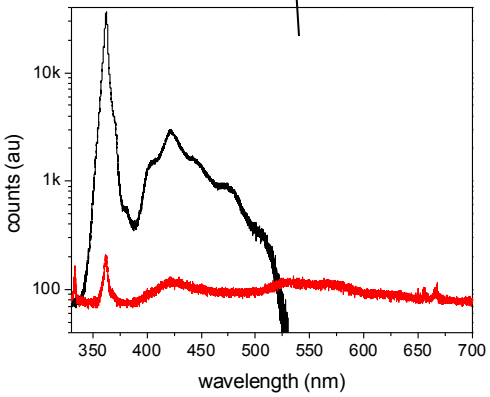
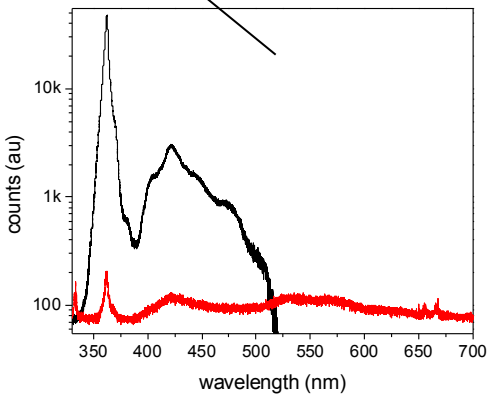








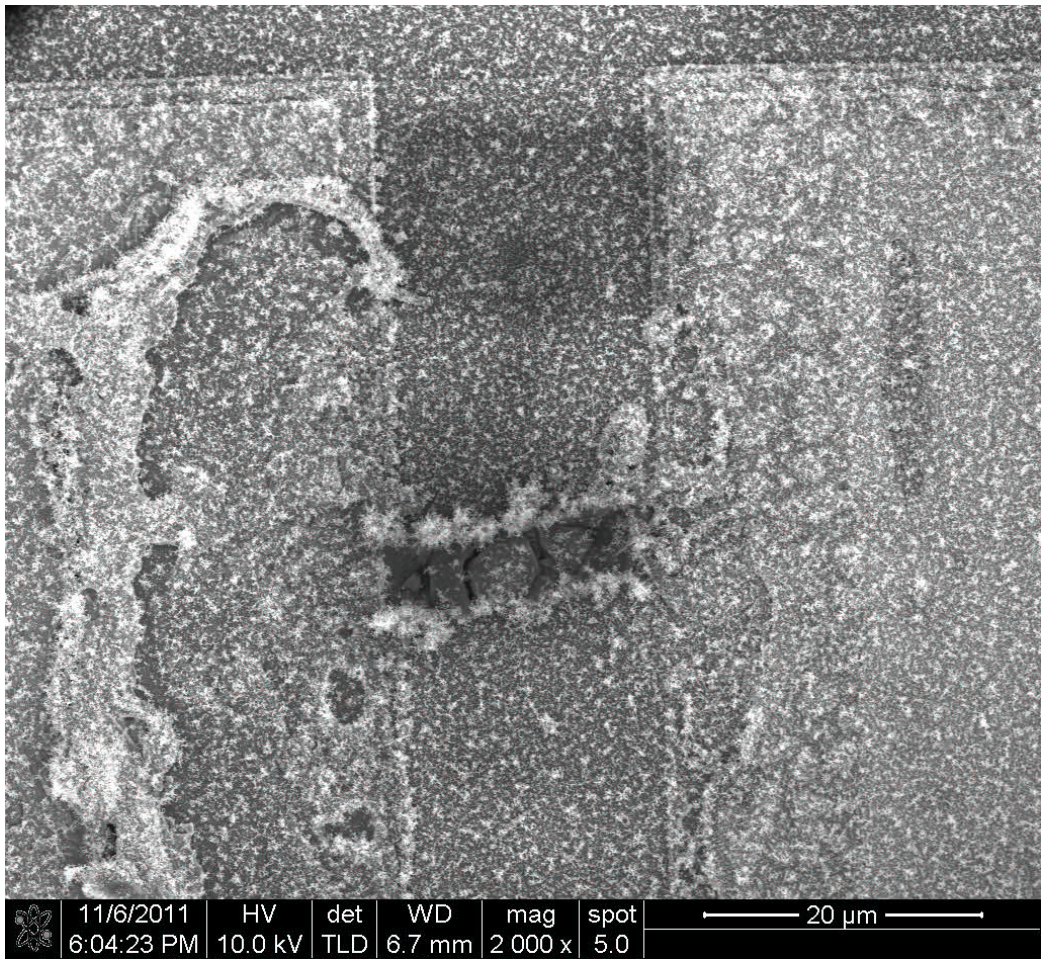


AFRL AlGaN/GaN HEMT TLM analysis (2219C)

Voltage step (1V/ 15min)stress up to 44V

Current loss from 65mA to 58mA

Catastrophic failure



Debris on surface is responsible for higher energy peaks